THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

BEHAVIOR OF FIBROUS AND NONFIBROUS COMPONENTS IN THE CORRUGATING OPERATION

PART II. BEHAVIOR OF MEDIUM IN SINGLE-FACER

Project 1108-22

Progress Report Two

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

May 1, 1960

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PART II. BEHAVIOR OF MEDIUM IN SINGLE-FACER

SUMMARY

A series of high-speed motion pictures have been taken showing the behavior of the corrugating medium at various locations in the single-facer. The present report is merely a brief description of the sequence in which the various locations photographed appear in the film which accompanies the report.

INTRODUCTION

In August, 1959 the Institute initiated, on behalf of the Fourdrinier Kraft Board Institute, a fundamental study of the mechanism of corrugating and the behavior of the fibrous and nonfibrous components in the corrugating operation. One of the goals of this study is the determination of the cause of "high-low" corrugations and leaning flutes as related to materials and process. It is believed that, from studies of this type, may proceed a better understanding of the environments to which a medium is subjected and the relationship between the physical properties of the medium which govern its behavior in terms of runability, molding, rigidity, and ability to bond readily. Eventually information of this type may be expected to lead to specifications and measurement of those properties desirable in a corrugating medium with implications, perhaps, for selection of the furnish.

The first step in this study was an analysis of the mechanism of corrugating, that is, the analysis of the stresses and strains imposed on the medium during the formation of the flutes. The analysis of the behavior of the medium from the time it leaves the parent roll until it passes the center of the labyrinth, i.e., the line joining the centers of the top and bottom corrugating rolls as formed flutes, has been completed and the results distributed in a report entitled, "Behavior of fibrous and nonfibrous components in the corrugating operation. Part I. Analysis of stress and strain in medium during formation of the flutes," Project 1108-22, Progress Report One

to the Fourdrinier Kraft Board Institute, February 29, 1960. Additional studies in this area, currently in progress, are concerned with the stresses and strains imposed on the medium as well as its behavior from the time it leaves the center of the labyrinth until it emerges from the pressure nip as single-faced board.

In the phase of the study which has been reported as well as in the phases currently in progress, high-speed motion picture photography has been used extensively to obtain photographic documentation of the behavior of the medium during its passage through the single-facer section of one of the I.P.C. experimental corrugators. These films have been most helpful for, by their study, it has been possible to obtain verification of anticipated behavior as well as behaviors which had not been anticipated. One set of films taken at eight different locations on the single-facer has been prepared for each member company of the Fourdrinier Kraft Board Institute.

PREPARATION OF FILM

The composite film which has been prepared for distribution to the various member companies of the Fourdrinier Kraft Board Institute shows sequentially the behavior of the medium when corrugated with a set of A-flute rolls of approximately 12-inch diameters. The contour used was Langston regular A-flute contour of approximately 36 flutes per foot. The particular corrugator used in this study was so designed that photographs could be taken at strategic locations in the single-facer. The corrugator is shown in Fig. 1. The locations at which photographs were taken in the accompanying set of films are shown in Fig. 2. The medium used in these films was from the same roll and the films were taken sequentially. The conditions of operation are listed below:

Type of medium	straw
Speed, f.p.m.	350
Web tension, lb./in.	0.5
Roll temperature, °F.	350
Adhesive	Starch
Viscosity, sec.	32
Gel point, °F.	142
pH	11.5

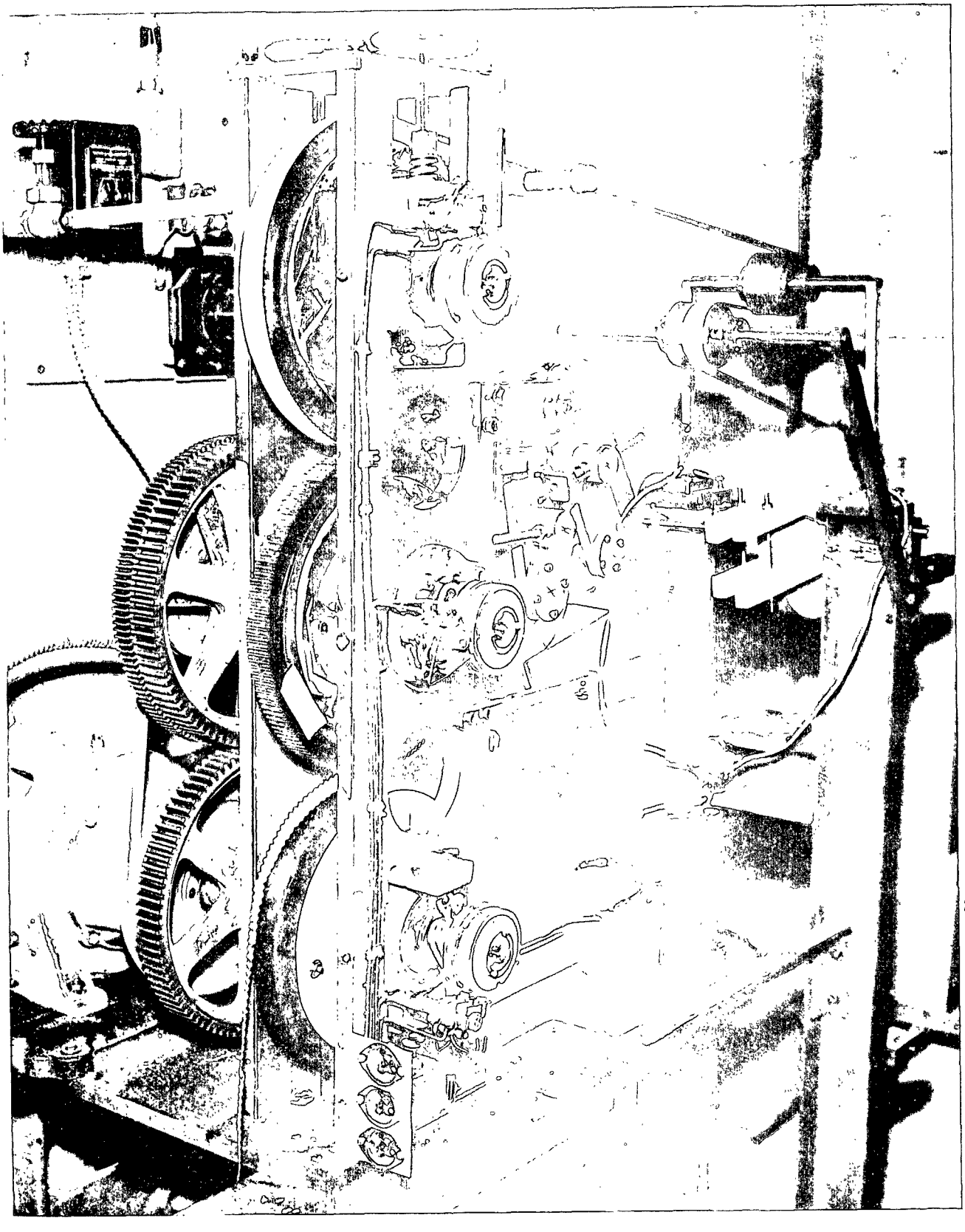

Figure 1. Photograph of Experimental Corrugator

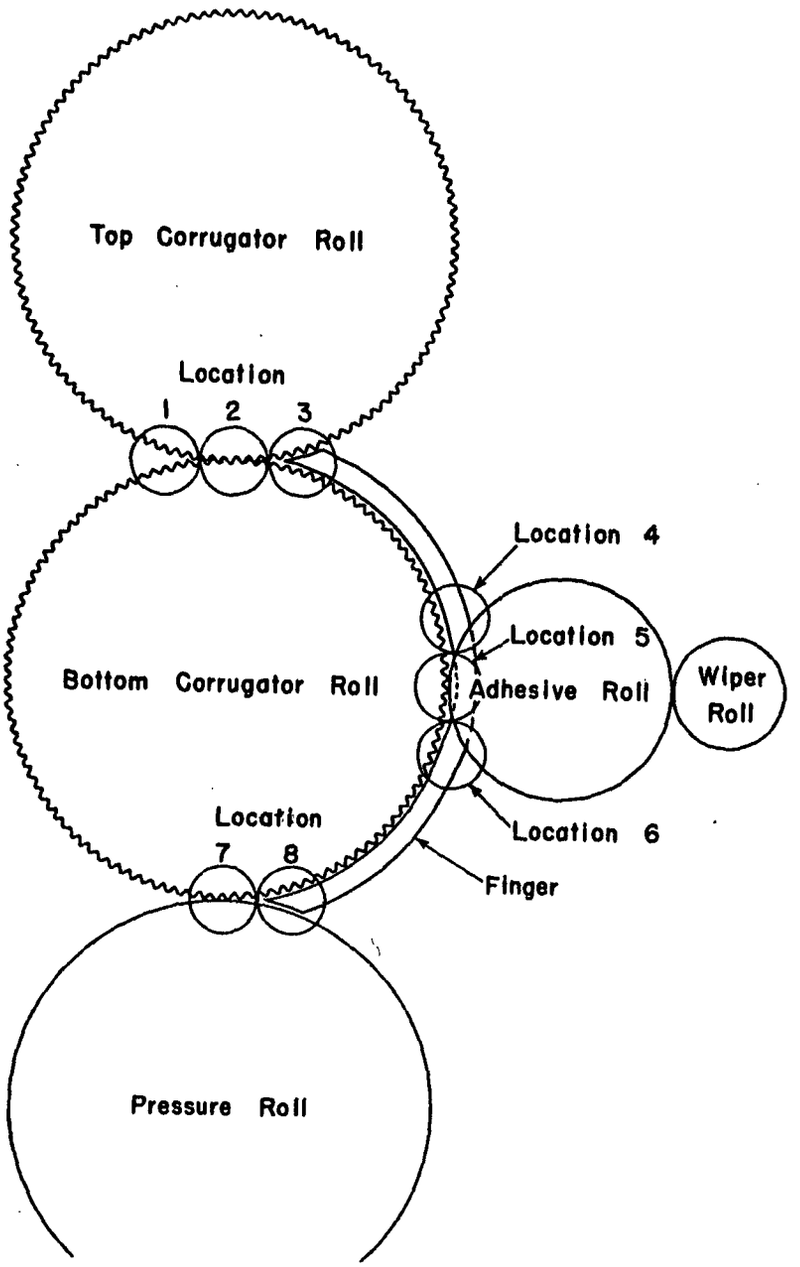

Figure 2. Schematic Diagram of Corrugator Showing Locations Photographed

The camera used was a Fairchild Motion Analysis Camera, Model HS 101. This particular model has a rated speed of 8500 frames per second; however, at 60 volts, one can get a speed of 9200 frames per second on the last 30 feet of film. The individual films were all taken at approximately 5700 frames per second.

The order in which the various locations appear on the composite film is as follows:

A. LOCATION 1

Location 1, as is shown in Fig. 3, illustrates the behavior of the medium as it enters the labyrinth of the corrugating rolls. Dark spots on the edge of the medium may be observed in the film. (Light spots in Fig. 3). These were purposely printed on the medium so as to observe more clearly the movement of the corrugating mediums relative to the top and bottom corrugating rolls. It may be observed also that, under the conditions of web tension used (0.5 lb. per lineal inch of width) the medium periodically bounces out of contact with the tip of the second flute to the left of the impacting tooth of the bottom corrugating roll. The "bounce" occurs simultaneously with the impact of the tooth of the bottom corrugating roll and apparently is a manifestation of the stiffness of the medium. This is not a characteristic of the particular corrugator because the phenomenon is observed on the Institute's Langston single-facer. The amount of bounce, however, appears to be related to the web tension--the greater the web tension, the less the bounce. At 1.5 lb. per inch web tension, the bounce is just barely distinguishable on A-flute rolls of the contour used in this study.

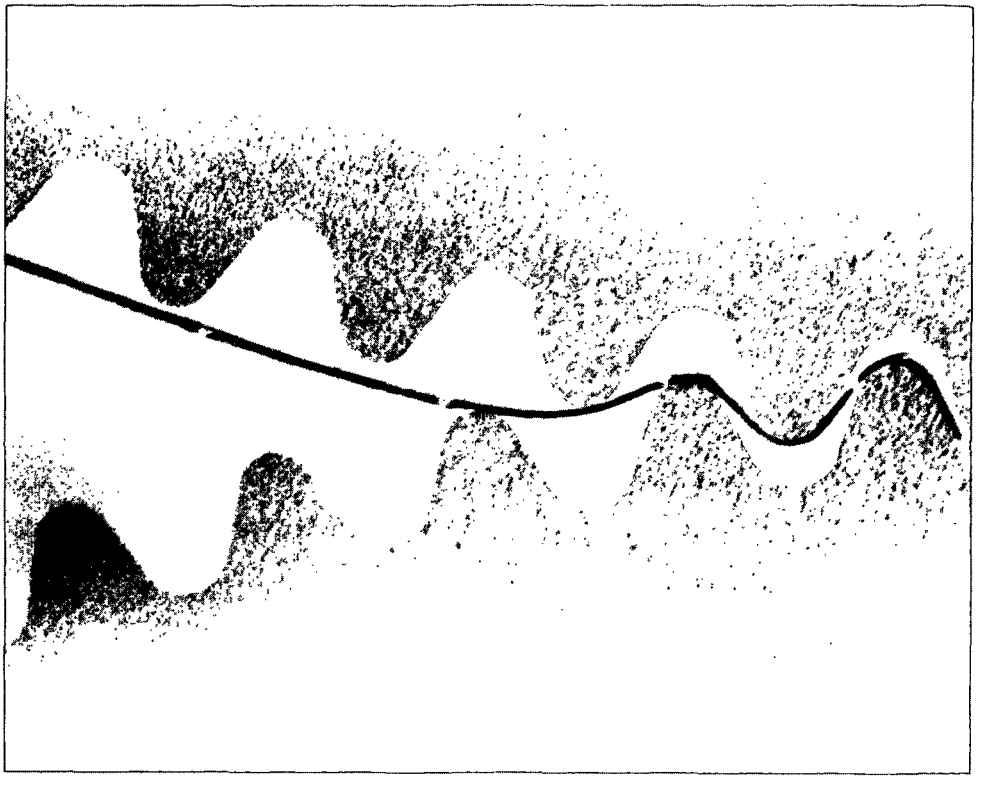

Figure 3. Location 1. Still of High-Speed Film Showing Medium Entering Labyrinth

B. LOCATION 2

Location 2 illustrates the behavior of the medium in the center of the labyrinth (see Fig. 4). It may be noted that the instantaneous rate of draw appears to diminish as the center of the labyrinth is approached. When the tip of a flute coincides with the line of centers of the two corrugating rolls, the clearance between the tip and the root of the corresponding mating tooth is a minimum due to the contour of the flute. In the case of the present contour, the flutes were cut so as to have a tip-root clearance of 0.006 inch when the shank (sidewall) clearance is 0.010 inch. At this point the flute of the medium is set by virtue of the extreme transverse compression which reduces the residual caliper at this point by about 35 to 40%. By close study it may be observed that there is evidence that this severe transverse compression results, in keeping with the mechanics of material, in a longitudinal elongation due to the Poisson effect. Further, it may be noted that there is no evidence of the "robbing" of medium from already formed flutes as has been voiced by many as the cause of high-low corrugations.

C. LOCATION 3

Location 3 corresponds to the exit of the formed flutes from the labyrinth. It may be noted (see Fig. 5) that immediately after the medium passes the center of the labyrinth, the flutes tend to spring away from the respective tip and root of the roll teeth. The degree of spring-back is controlled by means of the finger. It may be observed that the medium at the tip of the teeth on the bottom roll is retained by the finger. In other words, the restitution of the medium is such that the medium normally is forced against the finger. Further, it may be observed that the clearance

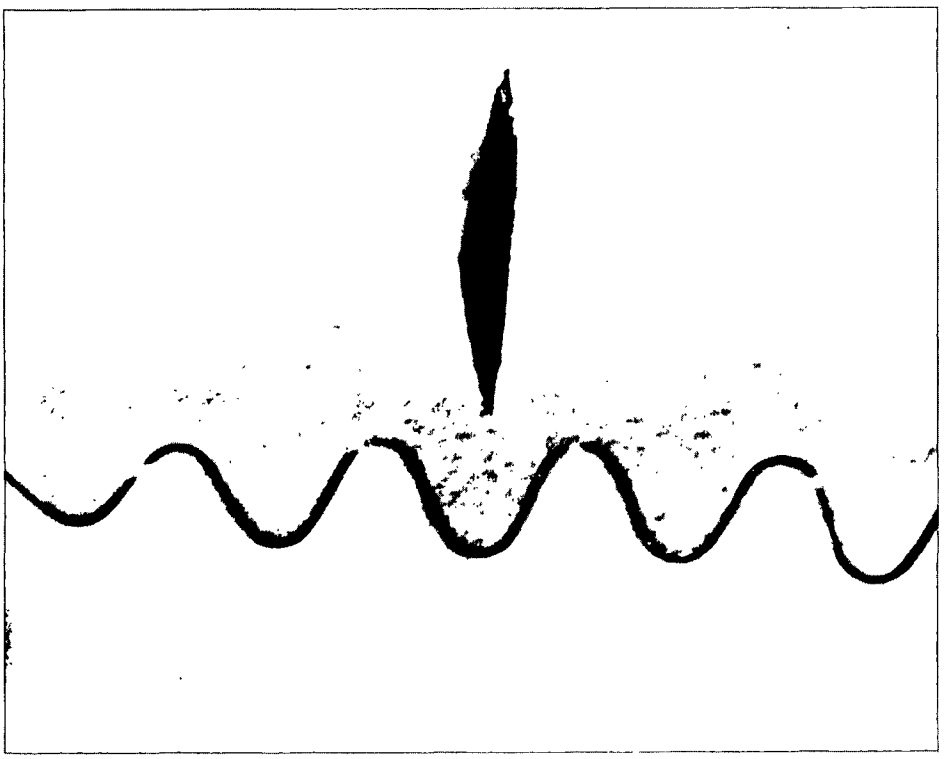

Figure 4. Location 2. Still of High-Speed Film Showing Medium in Center of Labyrinth

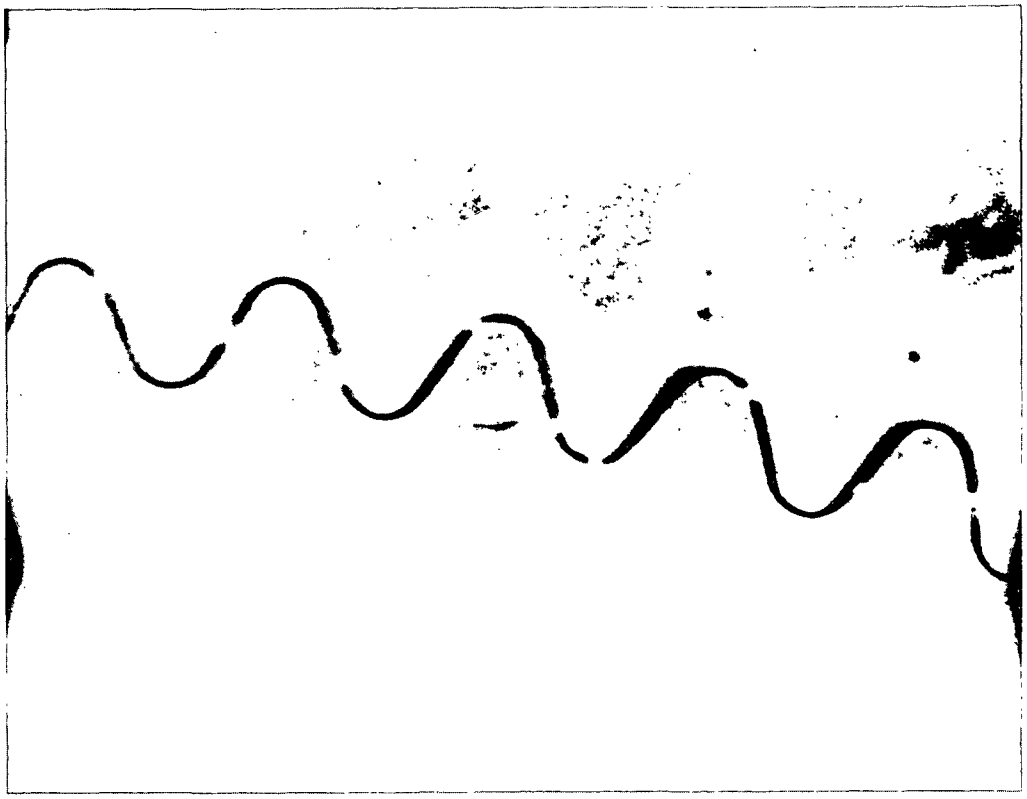

Figure 5. Location 3. Still of High-Speed Film Showing Medium Emerging from Labyrinth

between the root of the tooth and its associated fluted medium varies from flute to flute.

D. LOCATION 4

A still from the high-speed movie film taken at Location 4 is shown in Fig. 6. The area in view corresponds to the initiation of the "fluff-out" to receive the adhesive. As mentioned relative to Fig. 5, the flutes show varying degrees of clearance with the roots of the teeth; however, at this point the clearance is less than at the exit from the labyrinth (see Fig. 5). As was observed at Location 3, the medium is retained in approximate mesh with the teeth of the bottom roll by the finger. The finger has the form of the true arc of a circle except in the area of the finger relief. The relief in the fingers used in this study was approximately 0.052 inches. The start of the relief is indicated in the film by a vertical mark on the finger which has the appearance of a 4-penny finishing nail. It may be noted that, as the medium fluffs out, it travels on a path corresponding to an arc of an ever-increasing circle until it contacts the adhesive roll. This permits the flutes to rotate slightly as they move outward, with the rotation taking place with the flute tips and roots as the points of rotation.

E. LOCATION 5

The area of the adhesive assembly in the field of focus at Location 5 illustrates the behavior of the medium during the transfer of adhesive (see Fig. 7). It may be noted that the corrugated medium

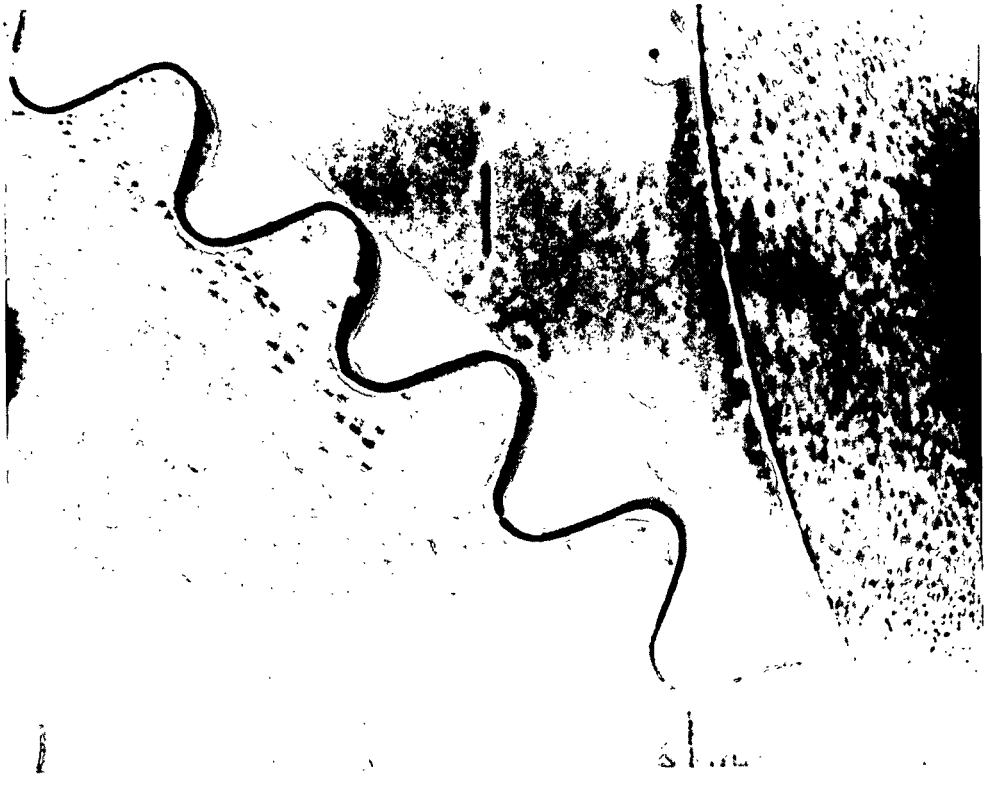

Figure 6. Location 4. Still of High-Speed Film Showing Start of Fluff-Out at Adhesive Rolls

Figure 7. Location 5. Still of High-Speed Film Showing Center of Fluff-Out at Adhesive Rolls

pushes outward against the finger and then the applicator or transfer roll pushes it back into the teeth of the bottom corrugating roll as it approaches the line of centers such that the medium "bottoms" in the roll except for an occasional flute which will probably show up in the single-faced board as a low flute. As the center line is passed, the medium adheres to the adhesive roll and is pulled out away from the teeth in the bottom corrugating roll until retained by the finger. The initiation of the splitting of the adhesive film may also be noted.

F. LOCATION 6

This location illustrates (see Fig. 8) the behavior of the medium as it emerges from the adhesive applicator. It may be noted that, after the fluff-out area, the corrugated medium is pushed back into more intimate contact with the bottom corrugating roll than was noted on the approach side of the adhesive applicator (see Fig. 4 and 5), although there is evidence of some of the flutes not "bottoming" as much as others. The splitting of the adhesive is very evident. Also, it may be noted that there are two instances wherein a substantially greater quantity of adhesive is transferred. Checks have shown that these are not due to an eccentricity of the applicator roll.

G. LOCATION 7

The behavior of the corrugating medium at the entrance to the pressure roll nip is illustrated in Fig. 9. It may be noted that, at the end of the finger, the corrugated medium "drops" out of mesh. This causes an appreciable distortion in the medium. Also, a quantity of adhesive collects on the end of the finger. In general, the medium starts to bottom well.

Figure 8. Location 6. Still of High-Speed Film Showing Medium after Fluff-out

Figure 9. Location 7. Still of High-Speed Film Showing Medium Entering Pressure Roll Nip

H. LOCATION 8

As may be noted in Fig. 9, Location 8 illustrates the behavior of the medium in the center of the pressure nip. It may be noted that all flutes do not bottom to the same degree. In addition, it may be seen that, as the flutes approach the point of tangency of both rolls, there appears to be a rotation of the flute tips. This is necessary in order to translate the curvilinear form into a linear form. On the bottom corrugating rolls, the distance between the tip of the flutes is greater than the form generated as combined board. Also, the tip distance is greater than the root distance because of being on an arc. The generated distance (in combined board) is the average of the root and tip distances. The tip of the teeth in the bottom corrugating roll appear to contact the trailing edge or side wall of the fluted medium. This possibly could influence the presence of leaning corrugations.

The high-speed motion picture films are currently being studied as a part of the analysis of the stresses and strains imposed on the medium during its travel through the single-facer. High-speed photographs are also being utilized in the study of the cause of "high-low" corrugations.

As a note of caution, the film should be stored preferably in a conditioned atmosphere because the base material will become brittle if stored in a hot, dry atmosphere. If the film should become embrittled, it may be reconditioned by a commercial film laboratory.

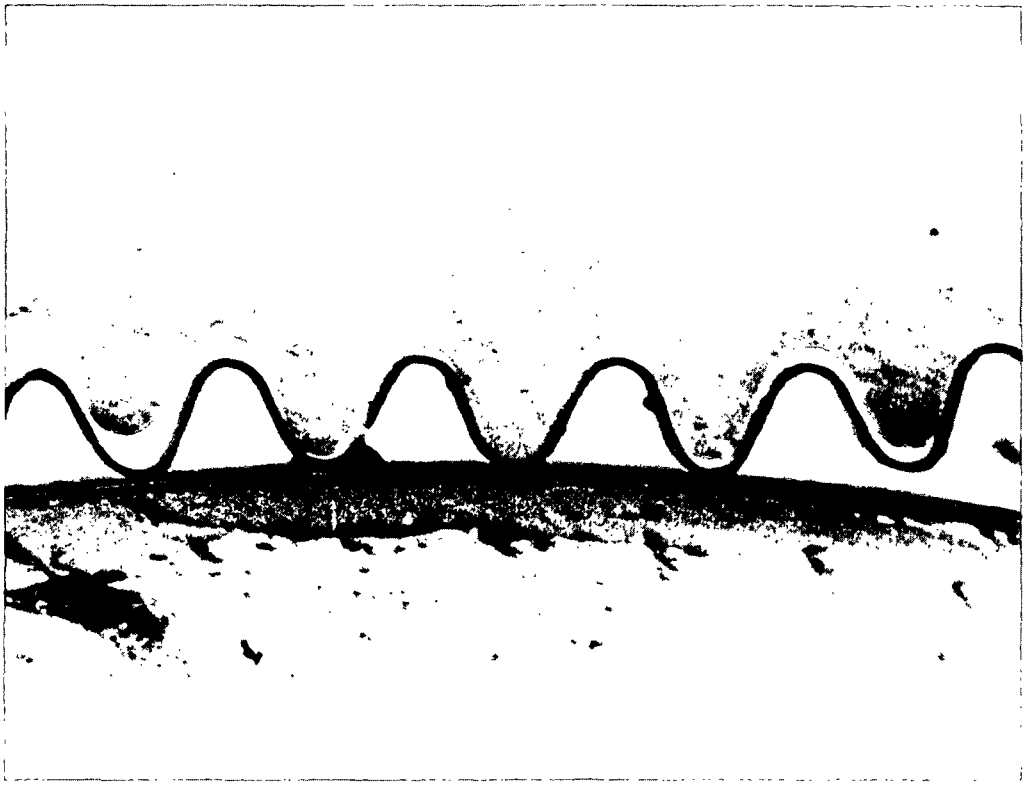

Figure 10. Location 8. Still of High-Speed Film Showing Medium in Center of Pressure Roll Nip

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R. C. McKee, Chief, Container Section